Glossopteris anatolica sp. nov. from uppermost Permian strata in south-east Turkey

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Synopsis

A full description is given of the leaf impressions recorded in 1962 as *Glossopteris* cf. *stricta* Bunbury from the Hazro flora in south-east Anatolia. Comparisons are made with several species from India, South America (Patagonia) and Antarctica. *Glossopteris anatolica* is regarded as an immigrant from the Gondwana Realm which reached the equatorial belt in latest Permian times. The composition of the Hazro flora is commented on in the light of a current revision.

Introduction

The presence of Gondwana elements in the Late Permian flora of Hazro in south-eastern Anatolia, Turkey, which is predominantly of Cathaysian affinity, has been reported by Wagner (1959, 1962). Most important in this respect was a species of *Glossopteris* which was compared with the Indian Gondwana species *G. stricta* Bunbury. Plumstead (in Discussion of Wagner 1962) criticized the identification and hinted strongly at the possibility that homeomorphy might have given rise to leaf shapes and venations similar to those of *Glossopteris* from Gondwanaland. The identification as *Glossopteris* was supported by Lacey (in Discussion of Wagner 1962) and by Archangelsky & Arrondo (1970: 81, footnote). Asama (1976: 203), on the other hand, regarded 'the plant reported from the Hazro flora as *Glossopteris* . . . to have been derived from the Euramerian plant *Lonchopteris* by Enlargement.' There is a marked difference between the fernlike fronds of the pteridosperm *Lonchopteris* and the *Glossopteris* type leaves of the Hazro region. The reference to Enlargement would tend to imply a comparison between pinnules and entire leaves, a comparison which cannot be sustained on morphological grounds. If Asama's principle of fusion and reduction is applied, there should be vestiges of scaled down, fused pinnules in the entire leaves found in the Hazro area. These do not occur. The Hazro specimens are sufficiently complete to dismiss the notion that large pinnules rather than entire leaves might be represented.

The original collection from Hazro was made in a single afternoon and in view of the considerable variety of plant remains obtained on that occasion, it seemed useful to return to the locality and to gather a larger collection. This aim was finally realized in 1979 and 1980 when R. H. Wagner had the opportunity to study the stratigraphical succession in the Hazro inlier, at about 70 km ENE of the provincial capital Diyarbakır, and to collect new material including several specimens of the disputed species of *Glossopteris*. A short list with partly revised identifications was given in Fontaine *et al.* (1980) and a paper providing stratigraphical details is being prepared in collaboration with E. Demirtaşlı of the Mineral Research and Exploration Institute of Turkey. The present paper is the first contribution to a full description of the floral elements collected from the Upper Permian rocks at Hazro. Foraminiferal data reported by Fontaine *et al.* (1980) have allowed dating the plant-bearing succession as Dzhulfian, i.e. the highest Permian.

Acknowledgements

R. H. Wagner is grateful to the Maden Tetkik ve Arama Enstitüsü in Ankara for the provision of facilities to study the Hazro area in the field. The companionship of E. Demirtaşlı has been appreciated above all and his considerable efforts in organizing the fieldwork are gratefully acknowledged; he also wishes to record the assistance given by Ahmet Angılı of M.T.A. The Research Fund of the University of Sheffield defrayed a large part of the travel expenses incurred by R.H.W.

The Royal Society of London and CONICET in Buenos Aires made it possible for S. Archangelsky to study the material from Hazro in the University of Sheffield, and to compare it with other species of *Glossopteris* in the collections of the British Museum (Natural History) and of the Sedgwick Museum in Cambridge, to which Dr C. R. Hill and Dr N. F. Hughes kindly granted access. Facilities at the Geology Department, University of Sheffield, are also gratefully acknowledged, and Howard Crossley is thanked for photographic assistance. The BM(NH) made a photograph available of the type specimen of *Glossopteris stricta* Bunbury which is reproduced here.

Systematic description

Order **GLOSSOPTERIDALES**

Genus ***GLOSSOPTERIS*** Brongniart 1822

Glossopteris anatolica sp. nov.
Figs 1–8, 11, 13–14

1959 *Glossopteris stricta* Bunbury; Wagner: 1379–1381 (*non* Bunbury 1861: 331; pl. IX, fig. 5).
1962 *Glossopteris* cf. *stricta* Bunbury; Wagner: 745–746; pl. 24, figs 2, 2a (part), fig. 3; pl. 25, fig. 5 (part), figs 6, 7, fig. 8 (part).
1980 *Glossopteris* sp. nov.; Wagner *in* Fontaine *et al.*: 919.

Diagnosis. Leaves extremely variable in size, the longest (incomplete) fragment measuring 10 cm × 3·4 cm at constant width (this specimen lacks both base and apex). Midrib strong, up to 4 mm wide, and consisting of several parallel strands; it persists into the leaf apex. Base of leaf acute, probably cuneate; apex obtuse (*c.* 90°), slightly emarginate in smaller specimens. Lateral veins decurrent, strongly arching near midrib and passing to the leaf margins at angles of 65° to 80°, which become slightly less in the apical part (*c.* 50°). Anastomoses and somewhat less common pseudo-anastomoses form a compact mesh with short areolae near the midrib (1·5–2 mm long and 1 mm wide) and passing into more elongate, narrower meshes towards the margins and in the apical part of the leaf.

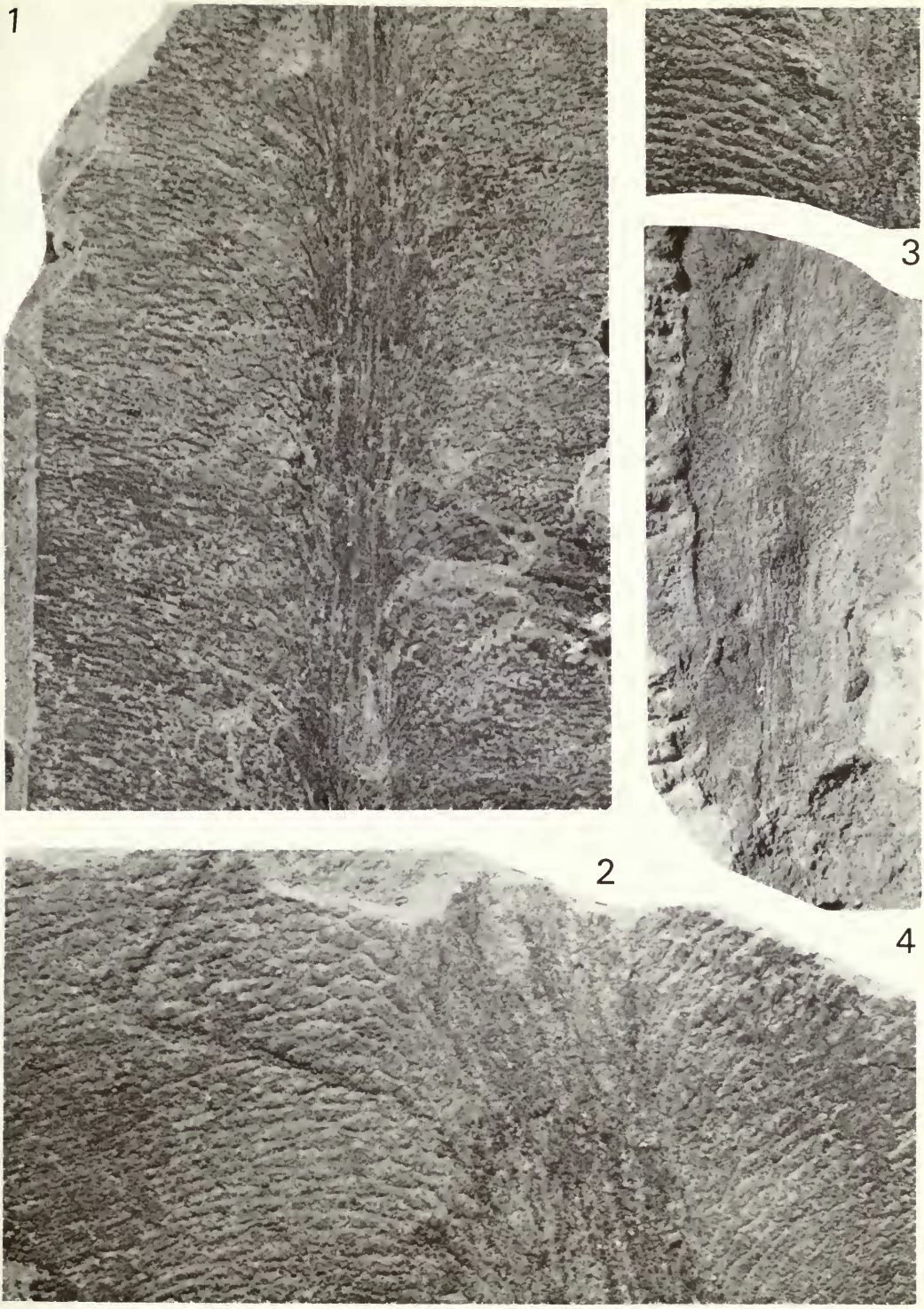
Holotype. British Museum (Natural History) register no. V.60797.

Paratypes. BM(NH) V.60793–6 and V.60798–801, and additional specimens from the type locality (Wagner loc. no. 3111) in the Natural History Museum of Maden Tetkik ve Arama Enstitüsü, Ankara.

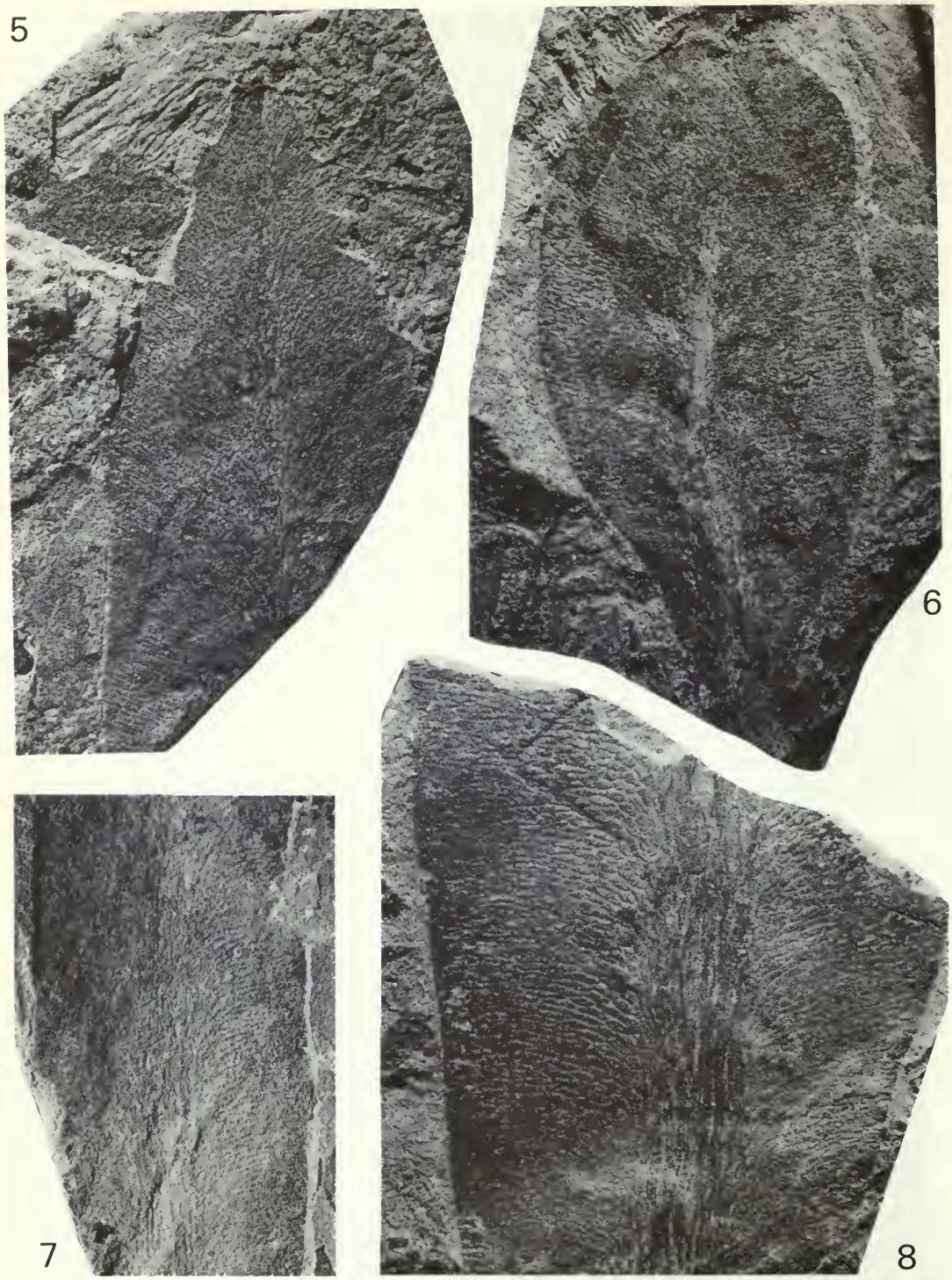
Type locality. Coal-bearing succession of the Gomaniimbrik Formation exposed at 750 m SSW of Dadaş village in the western part of the Hazro inlier, *c.* 70 km ENE of Diyarbakır in south-east Anatolia, Turkey.

Name. Anatolia, the Asian part of Turkey.

Description. The specimens figured in 1962 are joined by new collections made from different bands in the same general locality south of Dadaş in the western part of the Hazro inlier. Unfortunately, no complete leaves have been obtained, the most entire specimen (Fig. 6) being a rather small leaf, 4 cm long and 1·8 cm wide in the middle. It shows an obtuse, slightly emarginate apex. Larger specimens are up to 10 cm long (Fig. 1), despite the lack of preserved bases and apices. It is assumed that these leaves reached an approximate length of 15 cm or more. Their observed maximum width is 4 cm, and it thus appears that the larger leaves may have been narrowly oblong, lorate (following the terminology established by Dilcher, 1974, and



Figs 1–4 *Glossopteris anatolica* sp. nov. Fig. 1, middle part of a leaf showing a wide midrib and the characteristic lateral vein meshes, BM(NH) V.60793, ×3. Figs 2–3, middle part of leaf with characteristic venation, BM(NH) V.60794, ×6. See also Fig. 8. Fig. 4, basal part of a leaf, BM(NH) V.60795, ×3.



Figs 5–8 *Glossopteris anatolica* sp. nov. Fig. 5, apical part of a leaf, BM(NH) V.60796, ×3. Fig. 6, small leaf showing the base as well as a slightly emarginate apex, **Holotype** BM(NH) V.60797, ×3. Fig. 7, part of a small, narrow leaf, BM(NH) V.60798, ×3. Fig. 8, middle to near-basal part of leaf with a strong midrib and characteristic lateral veining pattern, BM(NH) V.60794, ×3. (Details of the same specimen, ×6, see Figs 2–3).

adopted for *Glossopteris* leaves by Chandra & Surange, 1979). Apical and near-basal leaf fragments were illustrated in 1962, and also appear in the new collections (Figs 4, 5).

The midrib is strong, always persistent to the apex, and rather wide in the basal part of the leaves. It consists of several (usually 5 to 6) parallel, non-anastomosing strands (Fig. 14). Lateral veins are decurrent in the basal and medial sectors of the leaves, and slightly less decurrent near the apex. They are strongly arching quite near the midrib (Figs 2, 7, 8, 11), i.e. within a distance of 4 to 5 mm, and run a straight, subparallel course in most of the width of the leaves, reaching the leaf margin generally at angles of 65° to 75° (overall variation is 50° to 80°). The vein pattern is reticulate throughout, with an apparent predominance of complete anastomoses, but also showing pseudo-anastomoses. The arching veins near the midrib show a mesh with short and wide areolae; more elongate, narrower vein meshes occur in the straighter, subparallel course of the veins towards the leaf margin (Figs 3, 13).

Comparisons. The most comparable species is *Glossopteris stricta* Bunbury, as described from the Upper Permian Kamthi 'Stage' of India (Bunbury 1861, Chandra & Surange 1979). The Anatolian species differs mainly in the secondary venation. Although the general pattern of vein meshes is similar, with short and broad areolae near the midrib and narrower, more elongate meshes towards the margin, it is noted that the veins of *G. stricta* are not quite as decurrent as in *G. anatolica*. They also meet the leaf margin at almost 90°, whereas the angle varies between 50° and 80° in *G. anatolica* (depending on the size of the leaf and the position of the veins within the leaf). Also, the apex of *G. stricta* leaves is more acute and does not display the emargination seen in at least one specimen of *G. anatolica* (Fig. 6). Although the general shape of the leaves appears to be similar in both species, it seems that the leaves of *G. stricta* are relatively longer (as follows from an examination of the lectotype, BM(NH) V.19620, which shows a length/breadth ratio of about 10:1). Making allowance for the incompleteness of the known leaves of *G. anatolica*, it appears that these show a length/breadth ratio of up to 6:1. The lectotype of *Glossopteris stricta* Bunbury has been refigured by Banerjee (1978: pl. 8, figs 17–18).

Glossopteris leaves described as *G. stricta* from Patagonia in South America (Archangelsky 1958a, b) are comparable to *G. anatolica* in the general shape, size and anastomosed vein pattern. However, the Patagonian leaves are different in having longer and narrower vein meshes near the midrib, and possessing less decurrent lateral veins. Complete specimens from Patagonia display a length/breadth ratio of 9:1, as against a probable 6:1 ratio for *G. anatolica*.

Glossopteris stricta Bunbury, as recorded from Antarctica by Plumstead (1962), shows somewhat less decurrent lateral veins which display a tendency towards free veining near the leaf margin (compare Plumstead 1962: pl. X, fig. 1; pl. XI, fig. 1).

Glossopteris indica Schimper, as revised by Chandra & Surange (1979), is a polymorphic species, with a changing length/breadth ratio as the species is followed up the stratigraphic column. Ratios of 6:1, 4:1 and 3:1 are recorded for the Barakar, Kamthi and Raniganj 'stages' in upward succession. The lateral veins of *G. indica* are not decurrent near the midrib, and they usually abut onto the leaf margin at angles of *c.* 45° to 50°, reaching angles of up to 70° in some medial portions. *G. anatolica* shows clearly decurrent veins near the midrib in the basal, medial and apical parts of leaves of all sizes. It is also noted that the apex in *G. indica* is more acute than it is in *G. anatolica*. Also it never appears to be emarginate.

Glossopteris pantii Chandra & Surange (1979) is a leaf of similar shape to that of *G. anatolica*, albeit with an obtuse-cuneate base as against an acute-cuneate base in the latter. Moreover, its veins follow a different pattern, being more horizontal in the medial sector and reaching the leaf margin at 45° in the basal parts of leaves. This contrasts with the venation of *G. anatolica* which is more generally uniform in different parts of the leaf. Also, the areolae near the midrib are shorter and wider in *G. anatolica*, which displays a more marked contrast in mesh size and shape between the central and marginal parts of the leaf.

Glossopteris arberi Srivastava (1956) shows leaves of similar size and shape to those of *G. anatolica*, but its lateral veins dichotomize only 2–3 times and the areolae are correspondingly longer than those of the Anatolian species.

Glossopteris tortuosa Zeiller, as figured by Plumstead (1952: pl. 49, fig. 4) from South Africa,

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Figs 9–10 *Glossopteris stricta* Bunbury. Fig. 9, lectotype (Bunbury 1861: pl. 9, fig. 5), BM(NH) V.19620, ×1. Fig. 10, detail of the venation of the lectotype (lower part of the leaf), ×3.
Fig. 11 *Glossopteris anatolica* sp. nov. Detail of the lateral vein meshes (for comparison with *G. stricta*), BM(NH) V.60799, ×3.

differs from *G. anatolica* in the shape of its leaves which are broadly ovate. It also shows narrower vein meshes near the midrib than occur in the latter.

Discussion. *Glossopteris* leaves have been found in three different bands in the Gomaniimbrik Formation south of Dadaş village in the Hazro inlier. They are common without being abundant, about 30 specimens having been found altogether. Every single specimen shows the characteristic nervation of *Glossopteris anatolica*, and it is clear that only a single species is represented. No cuticle has been recovered from any of these specimens and there are no fructifications assignable to *Glossopteris* associated with the leaf prints (Professor W. S. Lacey, who kindly examined some poorly-preserved fructifications from the original collection from Hazro, did not find convincing evidence of any *Glossopteris* fructification, although some specimens seemed to suggest the possibility – Lacey, *in litt.* 30.XI.62). On the other hand, the midrib composed of parallel strands and the characteristic mesh formed by anastomosed and pseudo-anastomosed lateral veins do not admit of a generic attribution other than to *Glossopteris*. The comparisons made with several undisputed *Glossopteris* species emphasize this point.

The Hazro flora

It remains to explain the presence of *Glossopteris* in an assemblage of plants which are mainly characteristic of the equatorial belt and not of the Gondwana Realm. A revision of the floral remains recorded in 1962 from Hazro, in conjunction with the new material collected from different bands in the same locality, has been undertaken by R.H.W. A revised list of taxa, incorporating additional species discovered most recently, is as follows: *Glossopteris anatolica* Archangelsky & Wagner sp. nov., *Bicoemplectopteris hallei* Asama, *Taeniopteris* sp., *Botrychiopsis* sp., *Fascipteris hallei* (Kawasaki) Gu & Zhi, *Pseudomariopteris hallei* (Stockmans & Mathieu) Wagner, *Cladophlebis tenuicostata* (Halle) comb. nov., *Sphenopteris* sp., *Pecopteris* (*Asterotheca*?) *calcarata* Gu & Zhi, *Dizeugotheca*? sp. nov., *Pecopteris nitida* Wagner, *Pecopteris pirae* Wagner, *Sphenophyllum* cf. *koboense* Kobatake, *Lobatannularia heianensis* (Kodaira) Kawasaki, *Cordaites* sp.

This is not the place for a full discussion of the revision which is still in progress. However, a few brief comments may be in order. *Bicoemplectopteris hallei* refers to the specimens figured as *Gigantopteris nicotianaefolia* in 1962 (see Asama, 1976: pl. XXX, fig. 6). *Fascipteris hallei* is the material recorded as '*Validopteris*' sensu Stockmans & Mathieu (*non* Bertrand) in 1962. *Cladophlebis tenuicostata* has been identified mainly from new material, but incorporates specimens recorded originally (Wagner 1962) as *Pecopteris tenuicostata* Halle and *Cladophlebis roylei* Arber. The new combination is based on *Pecopteris tenuicostata* Halle as figured and described from the Upper Shihhotse of central Shansi, China (Halle 1927: 99–100; pl. 26, figs 1–2). *Pseudomariopteris hallei*, *Sphenopteris* sp. and *Pecopteris calcarata* are new identifications based on specimens collected most recently. *Dizeugotheca*? sp. refers to a fertile pecopterid similar to that figured from Saudi Arabia by El-Khayal *et al.* (1980: fig. 2c). Sterile remains of this plant were illustrated in 1962 under the name of *Pecopteris* cf. *wongi* Halle pars (see also Lemoigne 1981: pl. 6, fig. 1). *Pecopteris nitida* Wagner, which is now available in large specimens showing the variation within the frond, also incorporates the remains identified in 1962 as *Pecopteris phegopteroides* (Feistmantel) and *Pecopteris jongmansi* Wagner. Recent investigations on the Permian flora of Unayzah in Saudi Arabia, undertaken by R.H.W. in collaboration with Dr A.A. El-Khayal of King Saud University, Riyadh, have shown that *Pecopteris tenuidermis* Wagner (1962) represents the cuticular imprints of pinnules of *Pecopteris pirae* Wagner. The single leaves of *Zamiopteris*? sp. figured in 1962 proved to belong to *Sphenophyllum* cf. *koboense* Kobatake, a Late Permian species in which the leaves show the development of a midvein.

Wagner (1962) claimed that the Hazro flora contained a mixture of Cathaysian and Gondwana elements. The Cathaysian aspect of this flora has not been seriously disputed, and the newly discovered additional species have strengthened the comparisons with the East Asian

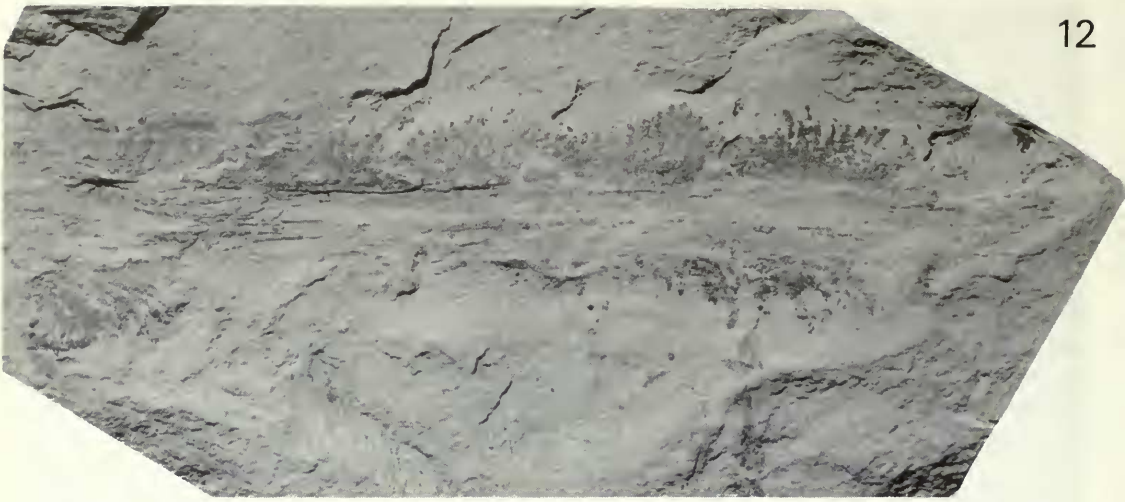

Fig. 12 *Botrychiopsis* sp. Basal portion of a frond showing a double row of pinnules, with totally fused lamina at the extreme base and more individualized, semicircular pinnules a little higher up. BM(NH) V.60802, ×3. Part of this specimen was figured by Wagner (1962: pl. 26, fig. 12).

Figs 13–14 *Glossopteris anatolica* sp. nov. Fig. 13, detail of lateral veins in the apical sector of a leaf, BM(NH) V.60800, ×3. Fig. 14, lower part of a leaf showing the wide, striate midrib formed by parallel strands, BM(NH) V.60801, ×3.

Cathaysia flora. The Gondwana component has been regarded as more controversial. *Glossopteris anatolica* is the most striking representative of the Gondwana flora at Hazro where it is of common occurrence. Its Late Permian (Dzhulfian) age puts it near the end of the stratigraphical occurrence of the genus, and this implies that the Anatolian species had sufficient time to migrate from the main area of the Gondwana Realm where *Glossopteris* is both diversified and abundant. The palaeogeographic position of India alongside East Africa and Madagascar provides the possibility of a direct migration route from either India or eastern Africa. The upper Mesopotamian region, to which Hazro belongs, can be regarded as the northernmost part of the Arabian Shield which forms part of the Gondwana Plate.

Another plant of Gondwana affinity in the Hazro flora is that figured as *Dicroidium*? vel *Thinnfeldia*? sp. by Wagner (1962: pl. 26, figs 12–13). Lacey (in Discussion of Wagner 1962) compared these specimens with the basal parts of the frond of *Neuropteridium validum* Feistmantel. He later referred to them as cf. *Gondwanidium validum* (Feistmantel) Gothan (Lacey 1975: 129) and quoted Archangelsky (1971, personal communication) as supporting this identification. Only two specimens are available from the old collection and no further remains have come to light. The most complete specimen is refigured here as Fig. 12. It was only partially figured in 1962. This specimen shows a wide rachis with fine longitudinal striations, and two lateral laminae with little differentiation in the basal part and gradually more individualized pinnules higher up. The venation of the individual pinnules is decurrent, dichotomous, and generally odontopteroid. The pinnules are broadly attached, and almost semicircular, being about twice as wide as they are high. There is a reasonable resemblance to the basal parts of fronds of *Botrychiopsis* (= *Gondwanidium*) as figured by Archangelsky & Arrondo (1971: pl. I). Three species of *Botrychiopsis* are known at present: *B. weissiana* Kurtz, *B. plantiana* (Carruthers) Archangelsky & Arrondo, and *B. valida* (Feistmantel) Archangelsky & Arrondo. The specimens from Hazro cannot be identified with any of these. Furthermore the Hazro flora is very Late Permian in age whilst the youngest of these species, *Botrychiopsis valida*, belongs to the Early Permian (for a recent description, see Archangelsky & Cúneo, 1981). Although it may be assumed that the Hazro specimens belong to a new species of *Botrychiopsis*, the material is inadequate for a proper description, particularly in view of the fact that *Botrychiopsis* fronds show a good deal of variation as a result of lobing. This variation can be brought out only by large specimens or many different fragments from a single locality. Since most of the Hazro flora is of Cathaysian affinity, a sustained search was made in the literature for any comparable species from the contemporaneous equatorial belt. This failed to produce results. The Hazro specimens are therefore assigned confidently to *Botrychiopsis* sp., and it is assumed that this is another immigrant from the Gondwana Realm.

Two other species mentioned in 1962 were also assumed to be indicative of a Gondwana affinity. One of these, *Pecopteris phegopteroides* (O. Feistmantel) (Wagner 1962: pl. 25, fig. 8 *pars*; pl. 28, fig. 26 – with cf.), cannot be retained in the list of species from Hazro. Fairly large fragments of the frond of *Pecopteris nitida* Wagner, which have been collected most recently, have shown that the specimens figured as *P. phegopteroides* fall within the range of variation of the latter species. The second putative Gondwana element, *Cladophlebis roylei* Arber (Wagner 1962: pl. 27, figs 16–17), is here referred to *Cladophlebis tenuicostata* (Halle) comb. nov. Additional material from the Hazro flora has shown a range of variation which apparently fits Halle's species from the East Asian Cathaysia flora. It is noted that *Cladophlebis mongolica* Durante, from the Permian of Mongolia, also seems to fit this species which Halle assigned to *Pecopteris*. Permian representatives of *Cladophlebis* are generally uncommon. They appear to be restricted to Upper Permian strata and it is assumed here that they are elements of the warm, humid, equatorial belt floras, which are found only occasionally in Upper Permian Gondwana assemblages.

General considerations on floral distribution

Wagner (1962) presented a map on which the Hazro locality was shown as belonging to both the Cathaysian (of the palaeoequatorial belt) and Gondwana realms. Chaloner & Lacey (1973) and

El-Khayal, Chaloner & Hill (1980) modified the northern boundary of the Gondwana Realm, leaving the Hazro locality well inside the palaeoequatorial belt. This is consistent with the information obtained most recently, which strongly emphasizes the Cathaysian connection. Also, the Saudi Arabian flora reported by El-Khayal *et al.* (1980), and which is currently being investigated in more detail, shows clear Cathaysian affinities. This flora is at present regarded as being of mid-Permian age. Lemoigne (1981) even referred to it as belonging to the Upper Permian. The boundary between palaeoequatorial (*sensu lato*) and Gondwana floras shown on the map published by El-Khayal *et al.* (1980), and which we accept as more nearly correct in the light of current information, leaves most of the Arabian Peninsula in the palaeoequatorial belt. The lack of information from southern Arabia and the horn of Africa makes it also possible that the northern boundary of the Gondwana Realm should be even further south, leaving the entire Arabian Shield in the palaeoequatorial belt (compare Lemoigne, 1981). Most palaeogeographic reconstructions place India alongside eastern Africa. These two areas are here regarded as the likely source for the two plants of Gondwana affinity in the Hazro flora, i.e. *Glossopteris anatolica* and *Botrychiopsis* sp. It is a well-known fact that Permian times saw an appreciable amelioration of climate which led to substantial mixing of floral elements. This is mainly recorded as the influx of 'equatorial', presumably more thermophile, elements into the Gondwana floras which thus became a little less restricted in composition. The reverse migration, from the Gondwana Realm into the equatorial belt, is less well documented, and it seems that the Hazro flora provides one of the rare examples of it. It is probably no coincidence that this migration is found in a flora of the latest Permian age. *Glossopteris* is almost exclusively a Gondwana element which lived in a temperate climate. The migration of *Glossopteris anatolica* to lower latitudes, and a warmer climate, may have been aided by the fact that the Hazro locality coincides with the northern edge of the Gondwana Plate in upper Mesopotamia. There seems to have been a continuous land area from East Africa/India to Arabia and Mesopotamia.

Another, more spectacular case of migration of the glossopterids is recorded by Zimina (1967, 1977), who figured and described three species of *Gangamopteris*, two of *Glossopteris* and one of *Palaeovittaria* from the region of Vladivostok in the Soviet Far East. These occur in the lower part of the Upper Permian.

'Gu & Zhi' (1974: pl. 110, figs 3–4) recorded a *Glossopteris guizhouensis* from the lower part of the Upper Permian in Guizhou (Kuichow) Province in China, but this species has recently been transferred to a new genus, *Abrotopteris*, which may be unrelated to the glossopterids. This species is currently described as *Abrotopteris guizhouensis* (Gu & Zhi) Mo (Zhao Xiuhu, personal communication).

Attention is drawn to Kon'no's (1963) record of *Glossopteris* cf. *angustifolia* Brongniart from the Permian deposits of Phetchabun in Thailand. Asama (1966), who studied the Phetchabun flora in more detail, accepted Kon'no's record in principle but mentioned that the specimen figured by Kon'no had an indistinct venation and that further collecting from the Phetchabun locality failed to turn up additional remains. In fact, he hinted at the possibility that the specimen might belong to *Taeniopteris*. The Phetchabun flora is in the East Asian Cathaysia Province.

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